Microphonics in the SSR1 325 MHz Spoke Cavity Operating at a Gradient of 5 MV/m and a Temperature of 4 K

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Over the last several weeks we have had another opportunity to study microphonics in the SSR1 325 MHz spoke cavity in the Meson Detector Building.

During these tests, the cavity was operating with a half-bandwidth of 102 Hz at a temperature of 4K. The cavity was driven by an Agilent RF generator though a solid state amplifier. The maximum attainable cavity gradient in the configuration tested was approximately 5 MV/m.

Previous studies using SSR1 had shown it was possible to lock the cavity gradient to the RF frequency with a precision of 1.5 Hz RMS with a peak detuning of 8 Hz over a twenty minute period. Very simple simulations showed that it might be possible to significantly improve those results by digitizing the 13 MHz IF waveforms using a high speed ADC as opposed to the combination of an analog down-converter and a 16-bit 100 kHz ADC.

During these tests the 13 MHz IF forward and probe signals were both digitized in a Lyrtech VHS digitizer with 14-bit 104 MHz ADCs and the signals were digitally converted to baseband in the onboard Virtex-IV SX-55 FPGA. The baseband forward and probe signals were mixed to give an I signal proportional to the magnitude of the probe signal and a Q signal proportional to the phase difference between the forward and probe. The phase difference was fed back to the piezo actuator through a filter or an integrator or a combination of both. The performance of a variety of different filters and integrators running on both the CPU and FPGA were examined during these tests.

Time for these tests was limited because the SSR1 cryogenic system was scheduled to undergo an upgrade to allow operation at 2K. Because of the limited time and because the Project X cavities are planned to operate with a narrower bandwidth, at higher gradients, and at 2K, the bulk of our effort was focused on improving our firmware and software to obtain the best possible performance rather than performing systematic measurements.

Even so, we demonstrated we could lock the cavity to the RF frequency with an accuracy of better than 0.5 Hz over periods of up to 20 minutes.

Figure 1 shows the detuning of the cavity over a period of approximately 25 minutes. The cavity is initially locked to the 325 MHz RF. Just after 17:08 (17.14 hours) the lock was dropped. As shown in the inset the cavity begins to track the He bath pressure. A few moments later FM modulation with a 50 Hz bandwidth was applied to the cavity drive frequency. The measured detuning tracks the modulation. After the modulation was removed, the briefly returned to tracking the He pressure before the frequency lock was restored.

With the exception of a single glitch at approximately 17:06 the cavity remained within 0.45 Hz RMS of the RF frequency during the time it was locked. The glitch is believed to be due to a problem in the firmware running on the FPGA at the time.

Figure 2 shows a histogram of the detuning (blue dots) during the period the cavity resonance frequency was locked to the RF. The detuning distribution is bimodal rather than Gaussian suggesting the detuning is limited by some systematic effect rather than noise. The green curve shows the histogram of a simulated signal consisting of a sine wave with additive Gaussian noise. The green curve reproduces the main features of detuning distribution well. This suggests the phase measurement may be contaminated by a sinusoidal frequency leaking into the baseband signal used to calculate the phase difference. Alternatively the detuning may be modulated by a cavity resonance.

In the event that leakage is responsible for the bimodal distribution, the width of the detuning distribution could be narrowed significantly by suppressing that leakage, perhaps to as little as 180 mHz.

Figure 3 compares the SSR1 detuning distribution to the distribution measured in HoBiCaT. The SSR1 falls much more quickly and shows no evidence of the long tails observed there although the duration of the SSR1 measurements was sufficiently long to draw any definitive conclusions.

The peak detuning of SSR1 during this test was 1.46 Hz. It is the peak detuning that drives the cost of the RF plant and operating budget for an accelerator using narrow bandwidth cavities.

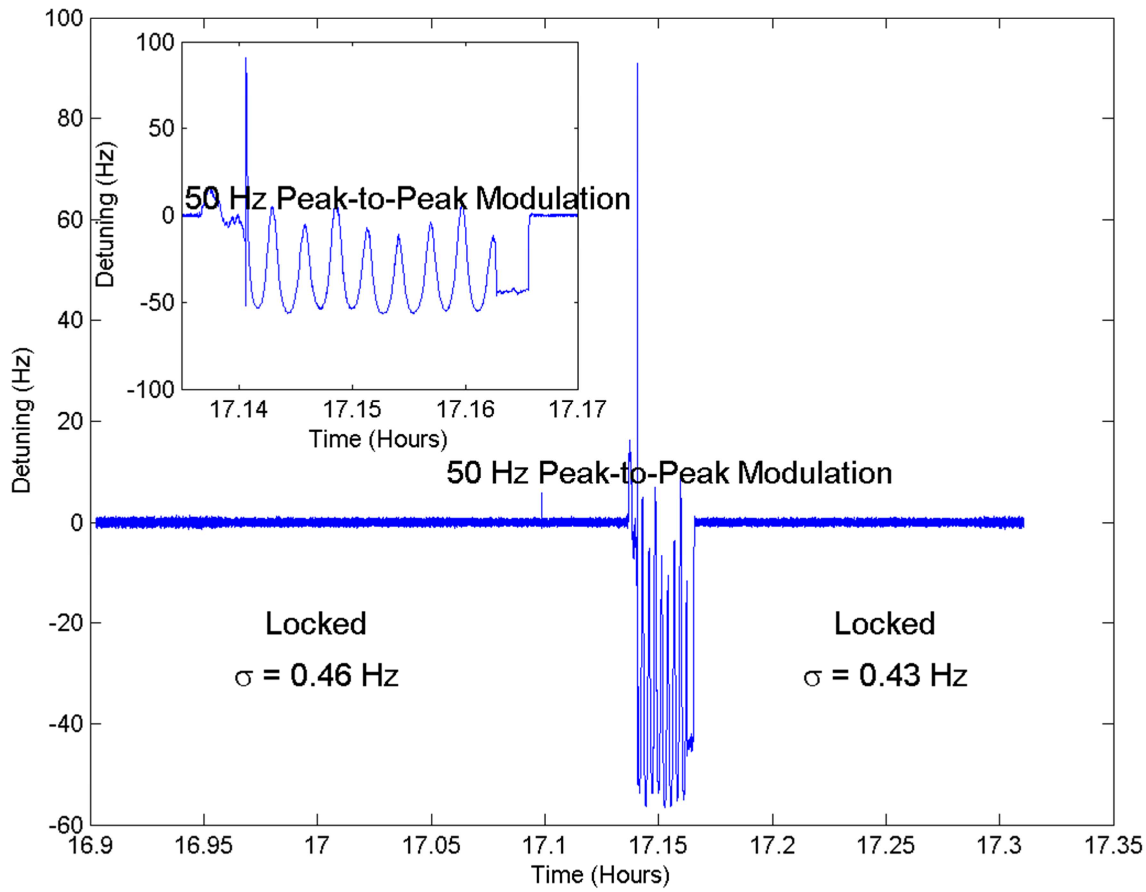


Figure 1: Detuning History

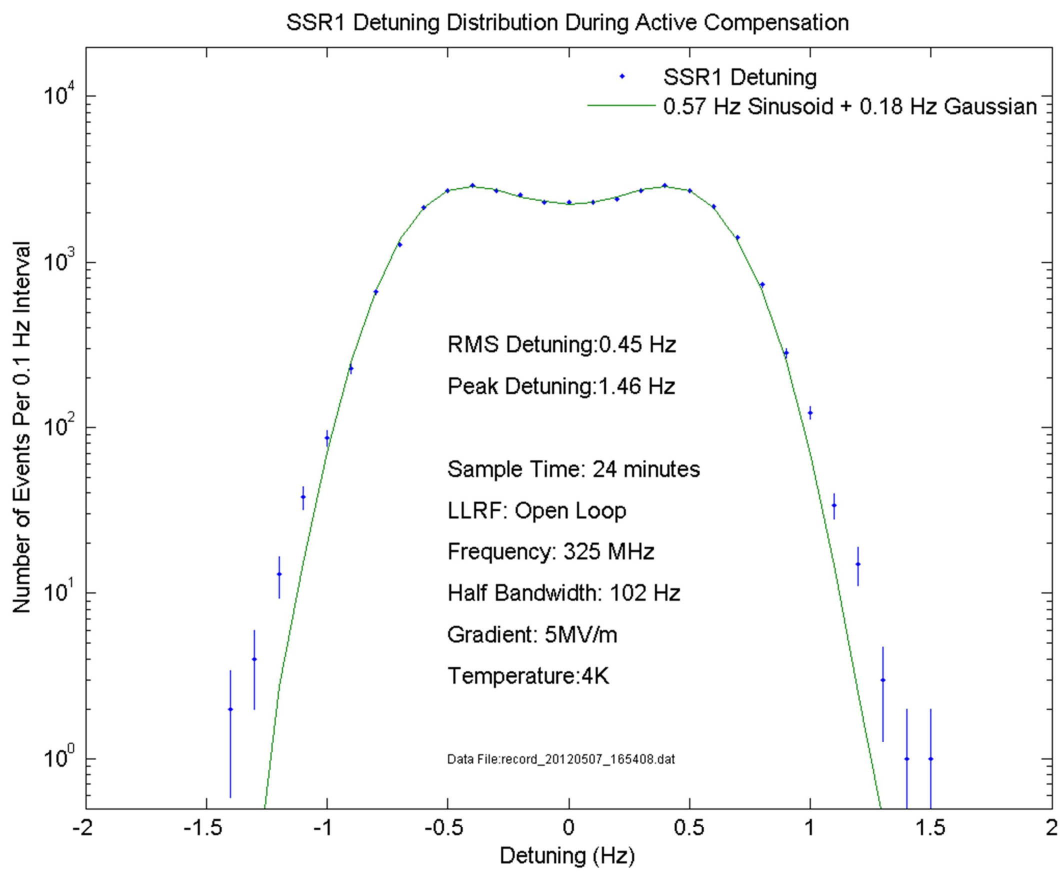


Figure 2: Detuning Distribution

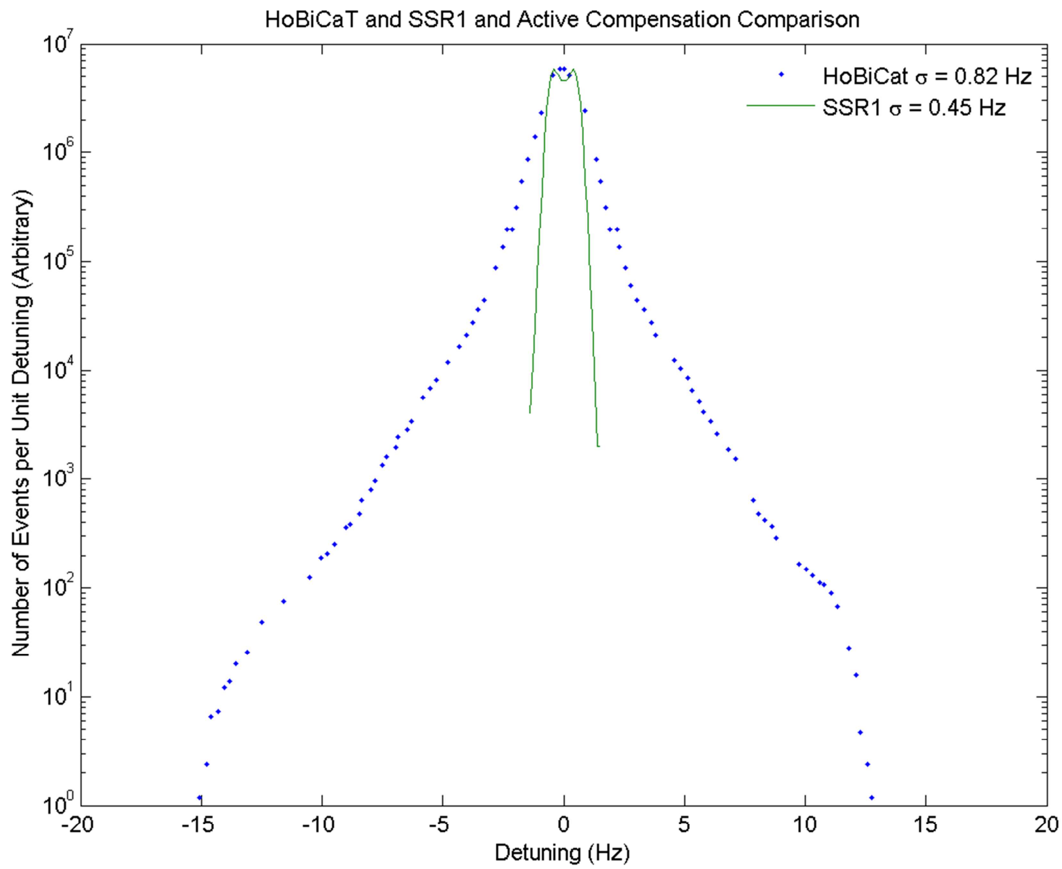
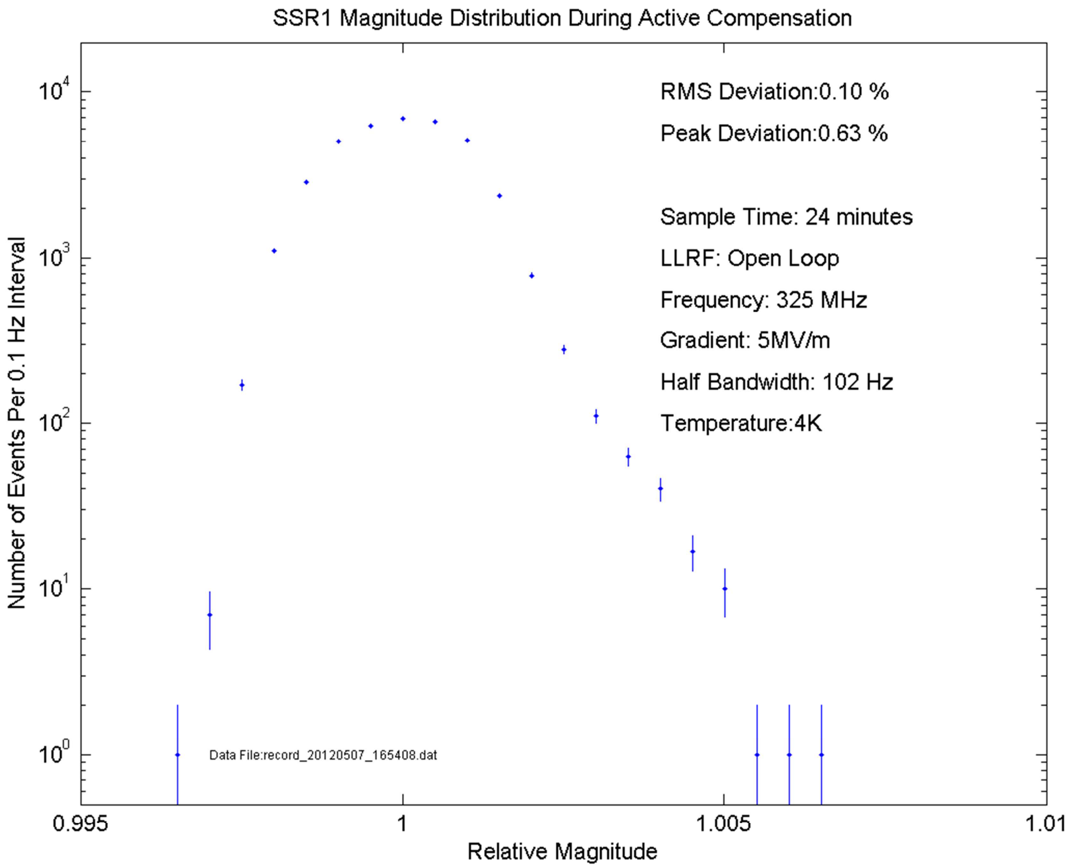
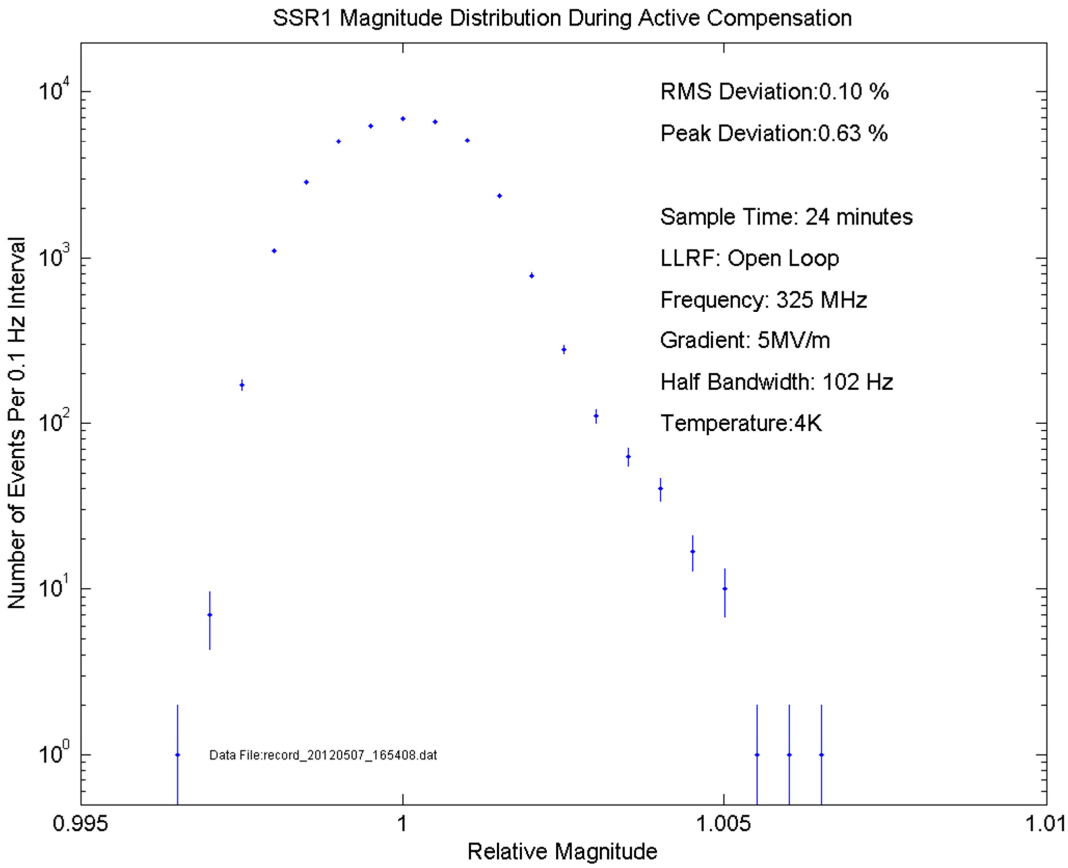


Figure 3: A Comparison of the SSR1 Detuning Distribution to HoBiCaT.



SSR1 Magnitude Distribution During Active Compensation
RMS Deviation:0.10 %
Peak Deviation:0.63 %
Sample Time: 24 minutes
LLRF: Open Loop
Frequency: 325 MHz
Gradient: 5MV/m
Half Bandwidth: 102 Hz
Temperature:4K
Data File:record_20120507_165408.dat
Number of Events Per 0.1 Hz Interval
Relative Magnitude
0.995
1
1.005
1.01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Frequency: 325 MHz
Gradient: 5MV/m
Half Bandwidth: 102 Hz
Temperature:4K
Data File:record_20120507_165408.dat
Number of Events Per 0.1 Hz Interval
Relative Magnitude
10^4
10^3
10^2
10^1
10^0
0.995
1
1.005
1.01